

Materials Science and Technology

Nanomaterials

Platinum Nanostructures for Enhanced Catalysis

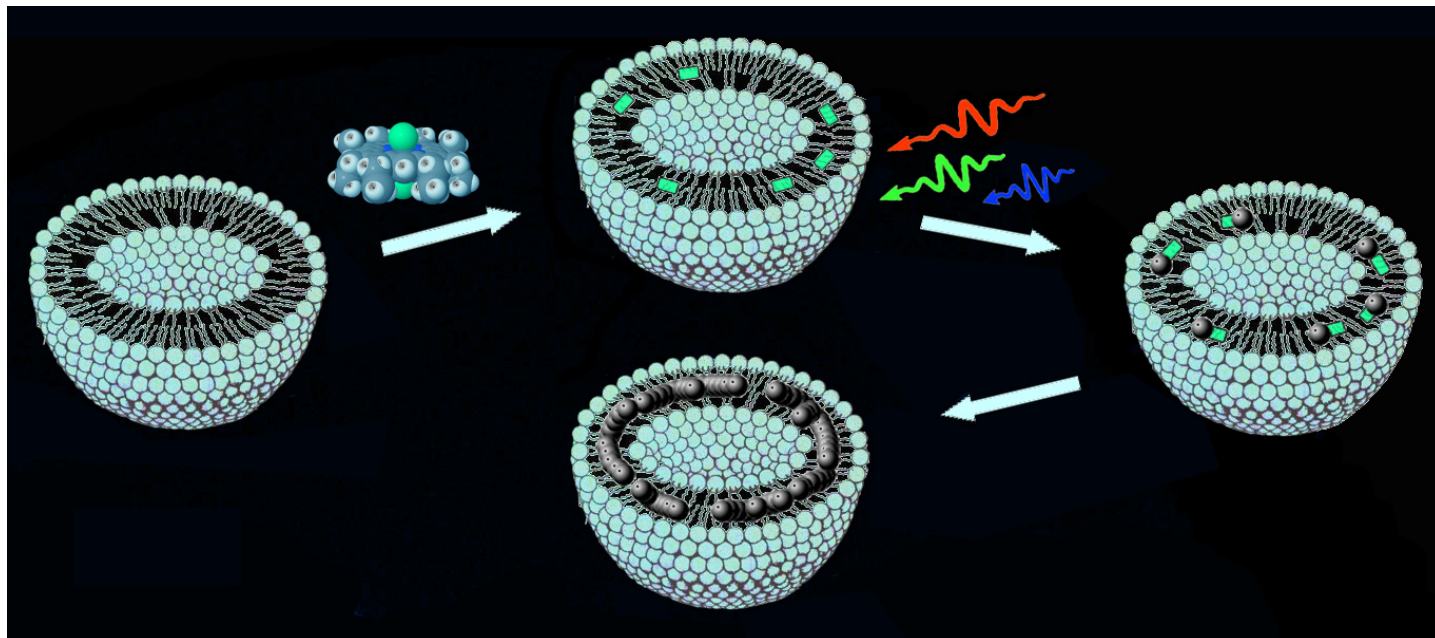


Figure 1: Schematic of how platinum nanostructures are formed. In this case, spherical surfactant liposomes, which incorporate photoactive porphyrins, template the reduction of Pt complexes into platinum metal at the porphyrin sites when exposed to light. The resulting Pt structures are shown in Fig. 2.

Complex platinum structures offer promise as improved catalysts in hydrogen fuel cells

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One of the promising renewable energy technologies today is the hydrogen-powered fuel cell. A key challenge for fuel cells in their ability to be a practical and cost-effective solution to meet energy needs is for more durable, efficient, and inexpensive electrocatalysts. Since it is well-known that platinum is the best substrate for catalytic reactivity, it is paramount that the rare and expensive material be used as sparingly and efficiently as possible. Sandia has developed an innovative approach for producing platinum catalysts at the nanoscale that offers much greater control over the shape, size, porosity, composition, stability, and other functional properties than those achieved by previous methodologies. Due to the high surface area and durability of the nanostructures, the process is expected to reduce platinum usage not only in fuel cells, but in other applications in the renewable energy sector as well.

The platinum nanostructures are produced by controlling the dendritic metal growth

that, under certain circumstances, occurs during the chemical reduction of aqueous platinum molecular complexes (Fig. 1). Dendritic growth produces branching metal arms that are approximately 3 nm in width with spaces between the branches of about 1 nm. Control over the structure is through a combination of a photoactive seeding method and the use of soft or hard nanostructured templates. Seeding is initiated by light absorption at porphyrins dispersed in the templates, followed by localized metal formation at these sites. Soft templates include surfactant assemblies such as liposomes (Figs. 1, 2), liposomal aggregates (Fig. 3), bicelles (Fig. 4), and worm-like micellar networks (Fig. 5); whereas, hard templates include inorganic or organic microspheres.

The electron micrographs in Figures 2-5 clearly demonstrate how the size and shape of platinum structures can be manipulated at the nanoscale. Of particular note are structures composed of dendritic "nanosheets,"



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such as the spherical dendrites shown in Fig 3. Remarkably, these structures can be transformed into “holey sheets” that exhibit enhanced structural durability under thermal, catalytic, and electrocatalytic reaction conditions. The structural durability comes from a resistance to ripening, a process by which small structural features become larger (e.g., during fuel cell operation) resulting in decreased active surface area. These ripening-resistant platinum nanostructures thus preserve the high surface area and catalytic activity.

Competing technologies mainly consist of platinum nanoparticles dispersed on conducting carbon substrates. Shaped platinum nanomaterials offer enhanced structural durability,

specific activity, and long range conductivity because of their extended metal structures. They also have advantages in the materials processing and fabrication of fuel cell electrodes. The Sandia technology is described and documented in ten patents and patent applications that have recently been licensed by Sandia to Compass Metals, Inc. for commercialization in the area of fuel cells. Compass Metals is also supporting a cooperative research and development agreement (CRADA) with Sandia to refine and improve the large scale synthesis of these novel catalytic materials for commercial use, to develop more advanced catalysts, and to investigate methods for their optimum use in fuel cells.

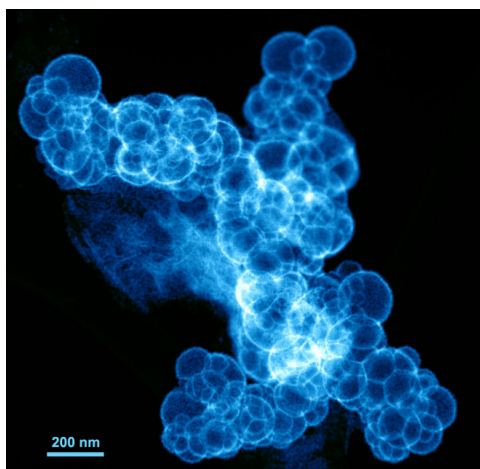


Figure 2: Pt nanocages produced by the method illustrated in Fig. 1. Each spherical cage is composed of many joined nanodendrites grown inside the bilayer of a unilamellar liposome.

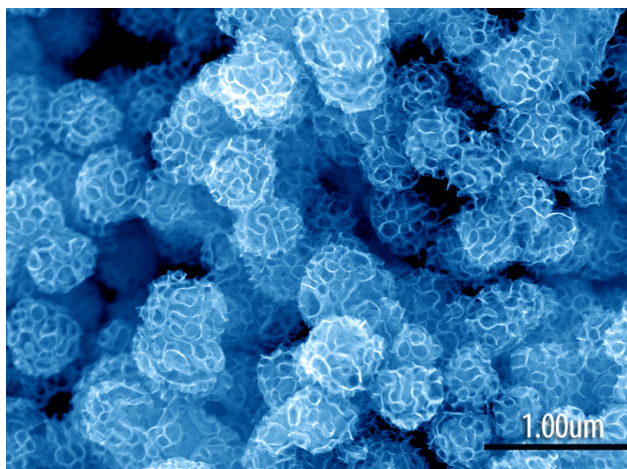


Figure 3: Platinum nanospheres composed of convoluted dendritic nanosheets templated by liposomal aggregates. The scale bar is 1 micron.

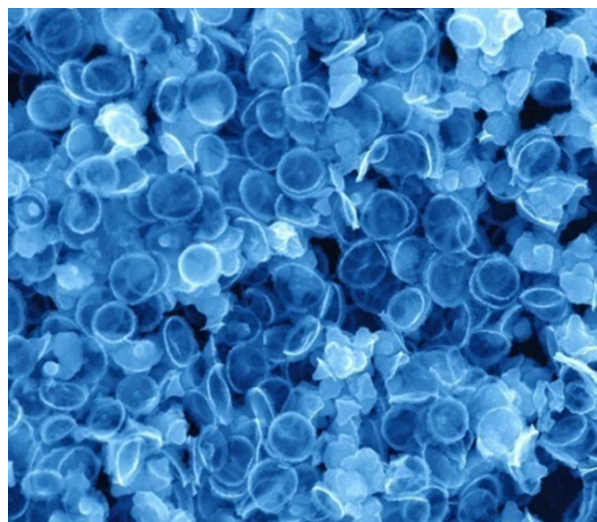


Figure 4: 300-nm platinum nanodisks templated by surfactant bicellar disks.

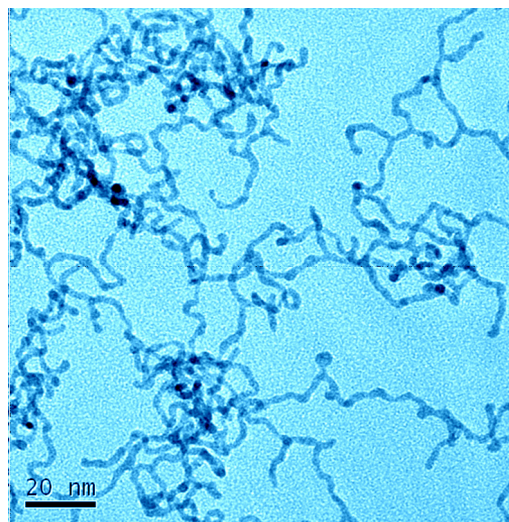


Figure 5: 2-nm diameter platinum nanowire networks templated by worm-like micellar networks.